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Summary

The goal of our research is to develop practical models and efficient algorithms to analyze and evaluate the reliability/availability/maintainability of complex systems in which component failures are statistically dependent and each component is subject to degradations before complete failure. The Event-Based Reliability Model (EBRM) was developed to model and analyze the reliability of a network in which component failures are statistically dependent. In EBRM, the events that could cause component failures were modeled explicitly. This approach required much less parameters than the traditional model employing conditional probabilities. The EBRM was also proved to be a completely general model which could be applied to various types of failure dependencies. For reliability evaluations, many existing algorithms for computing network reliability could be used with minor modifications and no significant increase in computational complexity. An improved algorithm for the approximate evaluation of network performance was also developed. For multi-state systems, ordered enumeration was used to approximate and bound system reliabilities and other performance measures, and an efficient algorithm was developed for this purpose. We have been studying network management algorithms which are resilient to network failures. Recently, we have developed the Cause-Based Multimode Model (CBMM) which allows us to consider failure dependencies of components which are subject to degradations. Practical and computationally tractable solution methods have been designed.

BASIC RESEARCH IN RELIABILITY FOR REAL SYSTEMS

Final Technical Report
Report Period 7/15/86 - 7/14/88
Grant No. AFOSR 84-0269

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Summary

The goal of our research is to develop practical models and efficient algorithms to analyze the reliability/availability/maintainability of complex systems in which component failures are statistically dependent and each component is subject to degradations before complete failure. The Event-Based Reliability Model (EBRM) was developed to model and analyze the reliability of a network in which component failures are statistically dependent. In EBRM, the events that could cause component failures were modeled explicitly. This approach required much less parameters than the traditional model employing conditional probabilities. The EBRM was also proved to be a completely general model which could be applied to various types of failure dependencies. For reliability evaluations, many existing algorithms for computing network reliability could be used with minor modifications and no significant increase in computational complexity. An improved algorithm for the approximate evaluation of network performance was also developed. For multi-state systems, ordered enumeration was used to approximate and bound system reliabilities and other performance measures, and an efficient algorithm was developed for this purpose. We have been studying network management algorithms which are resilient to network failures. Recently, we have developed the Cause-Based Multimode Model (CBMM) which allows us to consider failure dependencies of components which are subject to degradations. Practical and computationally tractable solution methods have been designed.

Research Objectives

The goal of our research program is to develop practical models and efficient algorithms to analyze and evaluate the reliability/availability/maintainability of complex systems in which component failures are statistically dependent and each component is subject to degradations before complete failure.

Accomplishments and Progress

We have concentrated on the performance modeling of networks with dependent and with multimode (or multistate) failures, and on network management algorithms which deal with these failures.

We have developed the Event-Based Reliability Model (EBRM) for the reliability modeling and analysis of real systems in which component failures are statistically dependent. Most existing reliability models assume that system component failures are statistically independent. This assumption, though it greatly simplifies the problem, is often not valid, and the result is usually an overestimation of network reliability. Some researchers have tried to model dependent failures by conditional probabilities with limited success. The major problem is that an exponentially large number of parameters have to be dealt with. The EBRM does not make use of conditional probabilities, but tries to model explicitly the events that cause component failures. Major advantages of EBRM over the traditional use of conditional probabilities include a reduction in the number of parameters to be handled and a physically more meaningful set of parameters. We have shown that the EBRM can be used to represent exactly the same kind of statistical dependencies between component failures as described by any given set of conditional probabilities. This means that the EBRM is a completely general model which can be applied to any kind of failure dependencies.

We have also developed a model to approximate the reliability of systems with multimode components. Previous research on reliability has been focused on models which assume that each component may be in one of two modes, namely, operative or failed. In real life, a component may undergo degradations in performance before a complete outage, and will therefore operate in more than two modes. Since it has been proved that the exact calculation of system reliability (even for two-mode models) is an NP-complete problem, we have developed an approximation method to

calculate this reliability measure. This method requires us to work with the states of the system in order of decreasing probability. An algorithm ORDER-M has been developed to generate these states in the proper order.

More recently, we have developed the Cause-based Multimode Model (CBMM), which allows one to consider failure dependencies of components which are subject to degradations. The model is very flexible and general and has physically meaningful parameters. Practical methods to approximate and bound network reliability and performance measures have been developed. They are based on a state enumeration approach using algorithm ORDER-M-II, which extends and improves ORDER-M. We have also generalized network reliability criteria to render them more meaningful when components may be in more than two states, and degradations may be correlated. Details of the model, solution methods, and generalized criteria can be found in Journal Publication #2 and #3.

The routing of messages in a network is an important problem. Proper network routing will enhance the probability messages will be correctly delivered, and reduce the network response time. We have developed a distributed diversity routing algorithm which is specifically designed for networks with fail-prone components. In particular, multiple copies of a message will be routed over disjoint paths in order to increase the probability of successful delivery. A performance model has been developed and it shows that, over a wide range of network parameters, our algorithm gives improved performance.

Research Personnel

Principal Investigator - Victor O. K. Li.
Graduate Research Assistants - Khiem Van Le, Shen-Neng Chiou.

Ph.D. Theses completed

1. Chiou, S.N., "Diversity Routing and Reliability in a Communications Network," Ph.D. Thesis, Department of Electrical Engineering, University of Southern California, May 1988.

Journal publications

1. Chiou, S.N. and Li, V.O.K., "Reliability Analysis of a Communication Network with Multimode Components," *IEEE Journal on Selected Areas in Comm.*, Vol. SAC-4, No. 7, October 1986, pp. 1156-1161.

2. Le, K.V. and Li, V.O.K., "Modeling and Analysis of Systems with Multimode Components and Dependent Failures." To appear in IEEE Trans. on Reliability, Special Issue on Distributed Systems, December 1988.

3. Le, K.V. and Li, V.O.K., "Generalized reliability criteria for Networks with Multimode components and dependent failures," submitted for publication.

Conference publications

1. Lam, Y.F. and Li, V.O.K., "A Survey of Network Reliability Modeling and Calculations," *Proc. IEEE MILCOM*, Monterey, California, October 1986, pp. 1.2.1-1.2.5.

2. Chiou, S.N. and Li, V.O.K., "Diversity Transmissions in a Communications Network with Unreliable Components," *Proc. IEEE ICC*, Seattle, Washington, June 1987.

3. Chiou, S.N. and Li, V.O.K., "An Optimal Two-Copy Routing in a Communications Network," submitted for publication.